bridge two, and the School Board seven members. With prophetic foreboding the commission suggests the prospect of revision in this department.

But if we have dwelt at length on the constitution of the local authority, it is not because its proposed functions are to be deemed satisfactory. On the contrary, the extent to which the secondary and technical education of the future is to be locally controlled *apart from the primary school* is far and away the chief blot upon, in most respects, an excellent production. Our readers know our views on this matter, and to this crucial point, which raises the very pinch of the problem of the future national education, we shall of course return again and again. Meanwhile, there can be little doubt that a strong endeavor will be made by the local authorities for primary education to put the thing on the right lines. They will get an opportunity in determining to resist the invitation to give up their higher grade and organized science schools, and we have no doubt they will rise to the occasion.

In connection with the financial proposals of the committee, we object most strongly to the diversion of the £100,000 now dispensed through the medium of small endowments to the elementary schools — unless, of course, this money is expended in provision of secondary departments of the elementary schools which now enjoy the endowment. No educational endowments, small as they are, are doing better work or are more needed. We should like, further, to know definitely what science and art grants are to be diverted, for let us at once say that the primary schools want all they now receive and more. Although the commission does not fear the result, we think the cause of technical education must suffer from the general appropriation of the whisky money for the purposes of secondary as well as technical education. We are sorry for this, because the secondary education the worker's child is distinctly technical, modern, and commercial.

It is not necessary to say that there is much fruit for the most serious contemplation on the part of the ardent educationist in the pages of this interesting and weighty report, and from time to time between now and the pleasure of the government it will be our duty to elaborate criticisms and comments on special points. Meanwhile, parting company as we are bound to do with the majority of the commission in respect of the recommendations affecting the local authority, its constitution and its functions, we nevertheless most heartily congratulate all concerned upon the production of a splendid contribution to the discussion in this country of the question of secondary education.

AN EFFECTIVE ORDER OF TOPICS FOR TEACHING PHYSICS[1]

THE conclusions which are intended to be met by this plan are the following:

1. We should teach physics as we would teach anything else that is worth

[1] From a privately printed paper, by Mr. Charles F. Warner, Cambridge, Mass.

knowing—for its own sake and with the same enthusiasm that every good teacher feels in awakening an interest in truth for truth's sake. Physics is really an interesting and useful science, even to a high school pupil. Let us not allow our zealous devotion to the scientific method to kill any natural desire of our pupils to know something worth knowing.

2. We ought to recognize the peculiar fitness which our science certainly has as a training ground for the mental faculties,—training in careful and methodical habits of work, in skillful use of the hands, in observation and reasoning, in scientific methods of investigation. This is the peculiar feature of the laboratory; and it must not be forgotten that individual work is the main thing here and that it must be carefully watched to have it valuable at all. But we may give all the training by means of our laboratory courses that is possible and yet fail, if we do not give something else also. We must furnish a great fund of information. Already the dead languages, because they have been taught for discipline, have lost in relative value among school subjects and will be saved, it is thought, by teaching more of their literature. If physics is taught for training only, it will need to be rescued from a similar decay.

3. There is no reasonable basis from the pedagogical point of view for separating physics for training from physics for its own sake, and no necessity in the nature of the subject for this division. Of course it must be admitted that there is a wide difference between a lecture or text-book method and a laboratory plan, both in the subjects best suited to each, and in the manner of presenting them. The point which I would make is this, that this natural difference of quality does not necessitate any alternative, either partial or complete. It is not necessary to adopt the whole of either one, to the exclusion of the other, nor, indeed, to place special emphasis upon either one, to the detriment of what is especially valuable in the other. Both methods may be combined, and still retain those distinctive features which give them their peculiar value. The field of physics is broad enough to furnish subjects suited to laboratory treatment, which are of practical value in themselves, and if the fruit of a considerable number of laboratory exercises is purely training, they can afford, in exchange, to yield some time to the consideration of those theories and principles which cannot be handled entirely by individual teaching, in the secondary schools at least, but which are of practical interest to all pupils, whatever their destination.

4. We ought to encourage reading and thinking about the theories of modern physics. The theory of the constitution of matter, the cause of the pressure of gases, the meaning of energy, its correlation and transformation, the ether with its gravitation, its heat, light, magnetism and electricity, I have found intensely interesting to most of my pupils; and they are boys supposed to have a bent toward practical things rather than matters of theory.

5. There is danger of making an unreasonable attempt to reduce all

laboratory work to a quantitative basis from the desire to obtain results in a form suited to a fixed plan for recording. To assist in making proper records, a certain quantitative form may be given to exercises which are really qualitative. From general educational considerations it is best to introduce the study of physics by bringing the pupil into close acquaintance with the interesting phenomena of the science. This work of introduction ought to cover the entire subject in a measure, and include very little, if any, quantitative work. The pupil should be given a general view of the elementary principles of the entire subject before entering upon any rigorous exercises, for three reasons,—first, the easier work is often the more interesting, second, the less exacting exercises are not entered upon with respect after doing work of a higher grade, and, third, the true spirit of quantitative investigation cannot come to the young student until he knows enough of the science, as a whole, to enable him to see the place which the results of the work he is given to do may have in the general system. Not until a general view of the entire subject has been obtained, can quantitative work be entered upon seriously and pursued with safety. A great practical advantage in this arrangement is that the advanced exercises may be graded according to their difficulty without much regard to the sequence of topics, inasmuch as the general subject is under review. This obviates the necessity of following some difficult exercise with easy ones, for, having once set a standard of accuracy, our course should be so planned as to favor living up to it.

6. The pupil should be led to discover things for himself whenever it is possible to do so. He should at the same time be protected from aimless experimenting. He should be taught to test rather than to verify. His experiments should therefore so far precede text-book reading and class discussion as to give him a fair chance to be scientific if he can be. This applies to the elementary qualitative work as well as to the later and quantitative exercises.

7. Laboratory teaching, both qualitative and quantitative, needs to be supplemented by the careful use of text-books and books of reference. A fair division of the time is two-fifths in the laboratory, two-fifths in class-room work, the remaining one-fifth being devoted to tests, and occasional lectures on special subjects.

OUTLINE OF TOPICS IN PHYSICS GRADED FOR EFFECTIVE TRAINING

NOTE.—About two hundred and fifty ordinary school periods are required to cover these topics in the manner outlined. Much less time is needed when the laboratory teaching can be conducted on the double-period plan. The course may be shortened to bring it within the compass of a school year by omitting the more difficult exercises, without losing the general view of the subject. Considerable variation in the order of topics is admissible and, indeed, desirable in adapting it to practical con-

ditions, if it does not go so far as to disturb the general plan. Some ot the easier quantitative exercises may be appropriately distributed among the qualitative experiments in the first four sections of the course.

Experiments described in Italics are thus emphasized as suitable for laboratory treatment.

I. PROPERTIES OF MATTER

(Statement and discussion aided by concrete illustrations)

Explanation of terms: Experiment; apparatus; manipulation; matter; body; general properties.

Most Evident General Properties and Conditions of Matter: Mass (distinguished from weight); extension (resulting in size or volume); impenetrability (*with experiment on impenetrability of air*); divisibility; molecule (limit of physical divisibility); porosity; compressibility and elasticity (distinguishing four kinds of elasticity—viz., after (1) compression (2) bending (3) stretching (4) twisting); states of matter (*a*) solid, (*b*) fluid (including liquids, vapors and gases); molecular motion (statement of theory of constitution of matter).

Molecular Forces: Molecular distinguished from molar forces; cohesion (involving adhesion); specific properties of matter: (1) tenacity (2) hardness (with experiment to compare several minerals according to Mohr's scale of hardness) (3) malleability (4) ductility (5) elasticity (perfect, imperfect, limit of), involving brittleness, flexibility, toughness and the processes of tempering and annealing; (6) viscosity (7) structure; surface tension (involving capillarity (with practical illustrations and experiment to determine the cause of capillary action; diffusion (with two optional experiments—one free diffusion, the other, osmosis).

Practical Questions: (Calling for explanations of phenomena pertaining to the foregoing topics).

II. SPECIAL PROPERTIES AND PHENOMENA

(Treated qualitatively)

HEAT: Sources (sun, fixed stars, chemical change, molecular motion); medium of transmission, ether; temperature; general effects of heat upon bodies,—(*a*) expansion, (EXPERIMENT, *Gravesands, ring or expanding bar moving index;* EXPERIMENT, *expansion of* (1) *water and* (2) *alcohol;* EXPERIMENT, *air thermometer;* principle of thermometers (involving a description of the construction of thermometers, and comparison of Fahrenheit with Centigrade scales); (*b*) abnormal expansion and contraction of water (practical illustration); (*c*) fusion and (*d*) vaporization (EXPERIMENT *to observe effect of solids in solution upon boiling point of liquid*); EXPERIMENT, boiling water in exhausted receiver; effect of pressure on boiling point; principles of evaporation; dew-point; EXPERIMENT *to determine the dew-point;* distillation (*experimental illustration*); transmission of heat (*a*) by conduction

(EXPERIMENT *to observe conduction through rods of copper and steel and through water*) (*b*) by convection (EXPERIMENT *with water and air;* principles of ventilation; (*c*) radiation (experiment with heated metal ball).

Practical Questions: (On phenomena connected with foregoing topics).

MAGNETISM: Historical notes; EXPERIMENT *to observe the general properties of a magnet;* definitions, (1) poles, (2) polarity, (3) equator, (4) axis, (5) consequent points, (6) induction, (7) retentivity; compass; EXPERIMENT *to observe the action of the poles of one magnet upon those of another;* the magnetic field; EXPERIMENT *to examine the field of magnets under various conditions;* magnetism of the earth; EXPERIMENT *to investigate the evidences of the earth's magnetism;* magnetic observations: (1) magnetic equator (2) magnetic poles (3) magnetic meridians (4) isoclinal lines; magnetic charts; deviation (1) local (2) on iron ships (3) methods of correction.

ELECTRICITY: Historical notes; static and current electricity distinguished; EXPERIMENT *to observe some of the evidences of electrification;* theory of electrification (involving discussion of ether); conductors and insulators; effect of neighboring charge upon an insulated body (1) polarization (2) bound and free electrification by influence; the electric field; the electroscope; the electrophorus; EXPERIMENT *to investigate the distribution of electrification upon insulated conductors* (1) *when found on hollow conductors,* (2) *effect of shape,* (3) *effect of points;* condensers: EXPERIMENT *with the electric pane;* PROBLEMS *requiring an explanation of the action of the plate machine and the influence machine;* potential; electro-motive force; current; EXPERIMENT *to observe conditions for voltaic current;* chemical principles involved and Grotthuss' theory; EXPERIMENT *to observe behavior of compass as an evidence of current;* the galvanometer; amalgamation; polarization; varieties of cells; EXPERIMENT *to observe how current is affected by nature* (resistance) *of conduct involving effect of* (1) *length* (2) *size* (3) *material of conductor;* the units ohm, ampere and volt; Ohm's law (*problems showing advantages of* (1) *arc and* (2) *series arrangement of batteries*); EXPERIMENT *to observe the arrangement of cells in arc and in series to form batteries;* EXPERIMENT *to observe the general effects of electricity* (1) *heat and light* (2) *electrolysis* (3) *electro-magnet* (4) *field of a wire in circuit* (5) *effect of live helix on a magnet; current and magnetic induction;* EXPERIMENT *with primary and secondary coils;* extra current; thermo-electric current; *Applications:* (1) telegraph (2) telephone and microphone (after lecture on sound) (3) shocking coil and spark coil (4) dynamo and motor (5) electro-plating.

SOUND: Condition of a body when emitting sound (practical illustration); medium for transmitting sound vibration (*practical illustration and reference to experience*); nature of wave movement explained; terms defined (1) crest (2) trough (3) wave-length; nature of sound waves (*experimental proof*); sound a sensation; mechanism of the ear; velocity of sound; reflection of sound waves (echoes); interference and re-enforcement of sound waves

(*illustrative experiment with tuning fork and resonance jars*)*;* nature of the vibrations of a sounding body (*illustrations with sonometer*) (1) nodes (2) antinodes (3) ventral segments (*further illustrations with rods, plates, and columns of air*)*;* the three properties of sound distinguished (1) pitch (2) intensity (3) timbre; *experimental proof of the cause of pitch* (*Savart's wheel and cardboard siren*)*;* intensity dependent on (1) amplitude (2) distance (3) density of medium; timbre dependent on composition of sounds; harmonics (1) of strings (2) of plates (*illustration*)*;* analysis of complex sounds by Helmholtz resonators (*illustration*)*;* the musical scale; beats, discord, harmony; the vocal mechanism; the phonograph.

LIGHT: Radiation by means of ether; theory of ether waves; light defined; ray, beam, and pencil defined; terms (1) luminous (2) illuminated (3) transparent (4) translucent (5) opaque defined; EXPERIMENT *to observe images through apertures;* shadow and section of shadow and penumbra (*illustrated by experiment and by diagrams*)*;* velocity of light; (Roemer's method explained); EXPERIMENT *to observe magnifying by pin hole;* visual angle and apparent size of objects; EXPERIMENT *to observe and state law of reflection;* diffused light; EXPERIMENT *to observe and describe images formed by plane mirrors* (involving a diagram); multiple reflection (diagrams to account for observations); EXPERIMENT *to observe and describe reflection from curved* (cylindrical) mirrors; reflection from concave spherical mirrors described with definition of terms (1) principal axis (2) secondary axis (3) vertex of mirror (4) center of curvature (5) principal focus (6) conjugate foci; *Problems to locate images of points in various positions;* real image; virtual image; images in convex spherical mirrors; EXPERIMENT *to observe and describe the refraction of light;* theory of refraction; EXPERIMENT *to observe total reflection;* lenses (1) converging (2) diverging; terms defined (1) principal axis (2) secondary axis (3) optic center (4) principal focus (5) focal length (6) conjugate foci; *Problem to locate the image of a point in various positions; Problem to draw diagram of real image: Problem to draw diagram of virtual image; practical illustration of decomposition of white light by prism;* theory of decomposition of white light: chromatic aberration; explanation of the rainbow: *Supplementary lectures on special subjects. Suggestive questions on optical instruments.*

III. THE MECHANICS OF FLUIDS

(Qualitative experiments and discussion)

Nature of fluids (involving comparison of gases and liquids); transmission of pressure by fluids; application in hydraulic press; EXPERIMENT *to investigate the relation of pressure to depth in water;* EXPERIMENT *to ascertain what the amount of pressure upon a given surface depends upon;* surface of liquids in connected vessels; EXPERIMENTS *to investigate the pressure of the air* (involving use of air pump); discussion of fluid pressure (atmosphere

described); barometers; elastic force of gases; EXPERIMENT *to observe the action of the siphon;* the siphon explained; the air-pump; the air condenser; the suction pump; the force pump; *Suggestive problems.*

Note.—The Principle of Archimedes and the work in Density and Specific Gravity is deferred in this plan until the practice in measuring and weighing is begun. But it might come here without seriously disturbing the order.

IV. THE MECHANICS OF SOLIDS

(Experiments, somewhat quantitative in character, and discussion)

Matter always in motion; inertia; action of force described; equilibrium of forces; measurement of force; graphical representation of forces; EXPERIMENT *to investigate the conditions for equilibrium for two forces;* EXPERIMENT *to investigate the conditions for equilibrium of three forces applied at different points in a body and not having one and the same line of action;* EXPERIMENT *to investigate the action of three forces that meet in a point;* EXPERIMENT *to investigate the conditions for equilibrium of three parallel forces; Problems in composition and resolution;* motion of translation and rotation; movement of a force defined; EXPERIMENT *to investigate the principle of moments;* cause of curvilinear motion; centripetal force, tangential force and centrifugal tendency; applications; the principles of gravitation with numerical illustrations of the law; theory of the estimation of mass by weight; center of gravity (mass); EXPERIMENT *to locate the center of gravity of several bodies;* EXPERIMENT *to investigate the conditions which give rise to three different kinds of equilibrium; Suggestive problems;* acceleration; laws of falling bodies; illustrative problems.

V. WORK AND ENERGY

(Discussion and illustration)

Work described and defined; energy, kinetic and potential; various examples; transference and transformation of energy; examples; unit of work and energy; formulas for estimating work and energy; conservation of energy; Joule's equivalent; power; *Problems.*

VI. MACHINES

(Experiments, discussion and problems)

The relation of machines to work (experimental demonstration with pulleys); general use of machines; general law of machines; special laws (1) of the lever and its modifications (2) of the inclined plane (experimental demonstration); suggestive problems.

VII. MEASUREMENT OF THE FUNDAMENTAL PHYSICAL QUANTITIES

The Measurement of Length and the Estimation of Surface and Volume: The units of length (1) English (2) metric; EXERCISES *in use of the metric*

rule with precision; line measure and end measure; the diagonal scale; EXERCISE *in use of diagonal scale;* the straight vernier; EXERCISE *in the use of the vernier;* EXERCISE *in reading barometer vernier;* rules for significant figures in computations; metric units of area; *Examples in computation of area;* metric units of volume; *Examples in computation of volumes, practical demonstration of the relations existing between similar surfaces and solids and the like dimensions;* estimation of the area of irregular figures (1) method of ordinates (2) method of weights; EXERCISE *in use of method of ordinates;* measurement of volume by displacement; EXERCISE *to test the accuracy of readings from the graduated tube;* EXERCISE *in use of the graduated tube in measuring volume;* EXERCISE *to determine the relation existing between the volume of a sphere and its circumscribing cylinder;* EXERCISE *to graduate a pipette for ordinary use;* units of angular measurement; EXERCISE *to practice the approximate graduation of a circle.*

The Measurement of Mass and the Determination of Density and Specific Gravity: Mass redefined; mass compared with weight; English and metric standard units of mass and weight; comparison of masses by inertia (illustrative exercise); rules for the use of the balance (1) zero point (2) arrestment (3) manipulation of weights (4) collecting results; weighing by counterpoise; double weighing; EXERCISE *in use of the balance* (1) *by ordinary method* (2) *by counterpoise* (3) *by double weighing* (*results compared*)*;* definition of density (1) absolute (2) relative; EXERCISE *to investigate the density of brass, steel, and cherry;* EXERCISE *to investigate the effect upon the weight of a body produced by the liquid in which it is immersed;* formulas for finding specific gravity (1) of bodies that sink in water (2) of bodies that float (3) of liquids; EXERCISES *in determining specific gravity* (10 *to* 15 *materials*)*;* specific gravity of soluble substance; floating bodies; hydrometers; specific gravity flask; EXERCISE *in use of hydrometer and specific gravity flask;* EXERCISE *to determine density of floating body from its degree of immersion;* specific gravity of gases; *supplementary exercises in specific gravity determinations by other methods* (optional); *numerical problems.*

The Measurement of Time: The standard units of time; time-keepers; the simple pendulum described; EXERCISE (*preliminary*) *to observe the conditions affecting the time of vibration of a simple pendulum;* EXERCISE *to determine the length of a seconds pendulum;* EXERCISE *to determine the relations between the time of vibration and the length of a pendulum; numerical problems.*

VIII. QUANTITATIVE EXERCISES

(Arranged in order of difficulty according to suggestions made by Mr. Chase of the Cambridge Latin School.)

1. Breaking Strength of Wire.
2. Elasticity (*a*) after stretching.

(*b*) after bending (optional).
(*c*) after twisting (optional).

Questions suggesting practical applications

3. Coefficient of Friction.
4. Action and Reaction.

Questions suggesting practical applications

5. Photometry—(Rumford's or Bunsen's method).
6. Focal Length of Convex Lenses.
7. Conjugate Foci of " "
8. Radius of Curvature of Convex Lenses. (Use of spherometer.)

Questions suggesting practical applications

9. Pitch of Tuning Fork.
10. Wave-Length and Velocity of Sound.

Questions suggesting practical applications

11. Testing Thermometers.
12. Coefficient of Linear Expansion of several Metals.
13. Expansion of Gas.
14. Boyle's Law.
15. Pressure of a Gas due to Heat.
16. Specific Heat of several Solids.
17. Latent Heat of Melting Ice.
18. " " " Steam.

Questions suggesting practical applications

19. Pulling Force of a Magnet.
20. Distribution of Magnetism (vibration method).
21. Electrical Resistance (substitution method).
22. " " (bridge method).
23. Measurement of Current (electrolysis).

Questions suggesting practical applications

24. Weighing by Vibrations.
25. Sensitiveness of a Balance.